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METHOD FOR WELDING STRUCTURAL MEMBER AND WELDED JOINT
[Kozo buzai no yosetsu hoho oyobi yosetsu setsugobu]

Tadateru Katayama, et al.

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INVENTORS	(72):	KATAYAMA, TADATERU; KAMURA, HISAYA; OKAMOTO, HARUHITO; KOJIMA, TOSHIFUMI; HIRANO, OSAMU
APPLICANT	(71):	NIPPON KOKAN K.K.
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[Claim(s)] /2*

[Claim 1] A method for welding and joining a structural member having a bevel in at least one member; said method for welding a structural member characterized by comprising the steps of: welding said bevel portion by butting end portions to be welded against one another; and performing a decorative buildup welding up to a distance range of at least 5 mm in the axial direction of the aforesaid member having a bevel from the beveled end on the surface side of the aforesaid member having a bevel.

[Claim 2] A method for welding and joining a structural member having a bevel in at least one member; said method for welding a structural member characterized by comprising the steps of: performing a decorative buildup welding on said surface up to a distance range of at least 5 mm in the axial direction from the beveled end on the surface side; and butting the end portions of the aforesaid decorative buildup welded member and another member to be welded with one another, and welding them to the aforesaid bevel portion and the upper layer of aforesaid decorative buildup welded portion.

[Claim 3] A method for welding and joining a structural member having a bevel in at least one member; said method for welding a structural member characterized by comprising the steps of: abutting end ports to be welded with one another and welding said bevel

*Claim and paragraph numbers correspond to those in the foreign text.

portions; and performing a decorative welding wherein the distance between the toe of a 1^{st} weld bead situated at the furthest position from the beveled end on the aforesaid surface side in the aforesaid member having a bevel and the toe of a 2^{nd} weld bead lap-welded on said 1^{st} weld bead is 15 mm or less, up to a distance range of at least 5 mm in the axial direction of the aforesaid member having a bevel from the bevel on the surface side of the aforesaid member having a bevel.

[Claim 4] A method for welding and joining a structural member having a bevel in at least one member; said method for welding a structural member characterized by comprising the steps of: performing a decorative buildup welding on the aforesaid member having a bevel wherein the distance from the toe of a 1^{st} weld bead situated at the furthest position from the beveled end on the aforesaid surface side in the aforesaid member having a bevel to the upper end of a 2^{nd} weld bead lap-welded on said 1^{st} weld bead being 15 mm or less, up to a distance range of at least 5 mm in the axial direction from the beveled end on the surface side; and butting the end portions of the aforesaid decorative buildup-welded member and another member to be welded with one another and welding them to the aforesaid beveled portion and the upper layer of the aforesaid decorative buildup-welded portion.

[Claim 5] A welded joint of a structural member having a bevel in at least one member; said welded joint of a structural member

characterized by having a decorative buildup welded portion which was decoratively welded up to a distance range of at least 5 mm in the axial direction of the aforesaid member having a bevel.

[Claim 6] A welded joint of a structural member having a bevel in at least one member; said welded joint of a structural member characterized by having a decorative buildup welded portion wherein the distance from the toe of a 1st weld bead situated at the furthest position from the beveled end on the aforesaid surface side in the aforesaid member having a bevel to the toe of a 2nd weld bead lap-welded on said 1st weld bead being 15 mm or less, up to a distance range of at least 5 mm in the axial direction of the aforesaid member having a bevel from the butt welded portion of said beveled portion and successively the beveled end on the surface side of the aforesaid member having a bevel.

[Claim 7] A welded joint of a structural member having a bevel in at least one member; said welded joint of a structural member characterized by having a decorative buildup weld heat affected portion nearly parallel to the surface of the aforesaid structural member having a bevel and whose toughness was improved by said decorative buildup welding by performing a decorative buildup welding comprising a plurality of weld beads in the axial direction from the beveled end on the surface side for said member having a bevel.

[Detailed Specifications]

[0001]

[Technical Field of the Invention] This invention relates to a method for welding a structural member in the construction and civil engineering fields and a heavy-gauge plate structural member.

[0002]

[Prior Art] When structural members were joined conventionally, they have been joined with bolts and by welding. In particular, in welding, the number of members is kept to a minimum and welding is frequently employed predominantly from standpoints of quickness of construction, ability to compete in terms of cost, etc. However, there is a problem because of a reduction in the toughness in the welding heat affected zone (called "HAZ" hereinafter) during welding. In particular, when an outside force acts on a building, the site where high stress in the welded joints between through-diaphragms and columns is anticipated is a major problem.

[0003] When diaphragms and columns are welded in a factory, conventionally a complete joint penetration welding is performed at a bevel angle of about 30 to 45 degrees to the steel plate on the column side. The welded portions and peripheral portions thereof are composed of welded metal, a HAZ, and the like in the high-strength portions. Normally, often the strength of the HAZ, and moreover, the toughness, with respect to the base material (steel) portion, are also reduced.

[0004] Therefore, assuming the concentration of stress develops in the vicinity of the welded portion, and ductile cracks develop

near the welded portion and propagate nearly perpendicularly to the direction of the stress in a region where the strength and toughness are low. This is a property of the ductile cracks.

[0005] In particular, in addition to tensile stress, flexural stress is also applied to the column-diaphragm joints. Due to restrictions caused by the diaphragm and weld overlay of the welding metal, a maximum stress point developed at a position further than the diaphragm. But in a welded joint with a single bevel, the possibility was high that a crack could propagate along the HAZ or weld line produced nearly parallel to the bevel face thereof.

[0006] Figure 9 is a cross-sectional explanatory diagram of a welded joint in conventional welding technology. In Figure 9, 11 is a column; 13 is backing metal; 20 is a through-diaphragm; 30 is welding metal; and 40 is a welding metal heat affected zone. The end portion of the column 11 is welded from the through-diaphragm 20 and welding metal 30.

[0007] Figure 10 is an explanatory diagram of a correcting bead corresponding to a decorative buildup welding shown in <u>Reikan Seikei Kakukei Kokan Sekkei·Shiko Manyuaru [Manual of Cold Molding Square Steel Pipe Design and Construction]</u> (published by The Building Center of Japan). In Figure 10, 30 is welding metal and 31 is decorative buildup welding metal. Normally the main purpose of a decorative buildup welding is form correction, as described in the above-

mentioned manual as "…when the correcting bead is filled in…after welding…to correct the shape of the place (welded toe portion)… ."

[0008] In addition, Figure 11 is a perspective view explaining a welding method using a steel outstanding in arrestability disclosed in Tokukai JP-A No. 2000-158127. In Figure 11, 11 and 12 are square steel pipes; 20 is a through-diaphragm; 21 is steel outstanding in arrestability; and 2 is H-shaped steel. This is a method for preventing brittle breakage at an angle of 20 degrees or more in the direction in which stress is applied to the weld line, and propagation of a brittle crack is arrested and interrupted by steel outstanding in arrestability.

[0009]

[Problems to be Solved by the Invention] However, there were the following problems with the prior art. That is, in Figure 10 when a decorative buildup welding was performed unintentionally, the base material sometimes hardened, and instead degraded the quality. In short, since such a phenomenon occurred no matter the strength of the steel plate, even if some kind of high-quality, high-strength material was used, destruction from the welded portion occurred first and did not lead to sufficiently manifesting the performance of the high-quality, high-strength material.

[0010] Moreover, even in the case of a steel with refined material to realize a higher strength upon devising a heat cycle and plastic work without increasing the amount of added elements during

rolling, the particle size of the structure of the steel refined during rolling returned to the particle size before being subjected to a temperature-controlled rolling, which resulted in the toughness of the base material decreasing markedly.

[0011] Moreover, in a beveled, welded part, sufficient advantages could not be anticipated merely by the material-improving effects on steel because of the factor controlled by details near welded portions, namely, a HAZ produced nearly parallel to the bevel face and a crack propagating along the weld line.

[0012] In Figure 11, by making the weld line diagonal in the direction of the stress, the region of the welded portion near the concentration stress is reduced. However, utilizing this prior art in the welding of members where the axial directions do not match was geometrically impossible; hence, the prior art could not be used for welding parts where the axes were orthogonal to one another or had angles besides 0 degrees, such as welding of columns and diaphragms. Furthermore, cutting the respective joined parts diagonally invited an extreme reduction in steel yield, and performing a difficult welding brought about a large-scale increase in cost.

[0013] Moreover, as a common problem of joints, there was the risk that cracks generated near a softened HAZ normally could develop from the welding metal portion when there was not sufficient overlay or strength in the high-strength portion comprising the welding metal. In order to solve the above problems, it is an object of the present

invention to provide a method for welding a structural member and a welded joint having the ability to control the propagation of cracks in a base material by propagating cracks generated in the vicinity of a welded portion to within the base material by keeping the reduction in the toughness of the base material to a minimum.

[0014]

[Means for Solving the Problems] The present invention is a method for welding and joining a structural member having a bevel in at least one member, which is characterized by comprising the steps of: welding said bevel portion by butting end portions to be welded against one another; and performing a decorative buildup welding up to a distance range of at least 5 mm in the axial direction of the aforesaid member having a bevel from the beveled end on the surface side of the aforesaid member having a bevel. Moreover, the term “decorative buildup welding” herein includes a general decorative buildup welding performed mainly for the purpose of correcting a form but whereby strength can hardly be anticipated, and also, a welding whereby the same strength as a butt welded portion can be anticipated.

[0015] Moreover, the present invention is a method for welding and joining a structural member having a bevel in at least one member, which is characterized by comprising the steps of: performing a decorative buildup welding on said surface up to a distance range of at least 5 mm in the axial direction from the beveled end on the surface side; and butting the end portions of the aforesaid

decorative buildup welded member and another member to be welded with one another, and welding them to the aforesaid bevel portion and the upper layer of aforesaid decorative buildup welded portion

[0016] Furthermore, the present invention is a method for welding and joining a structural member having a bevel in at least one member, which is characterized by comprising the steps of: abutting end ports to be welded with one another and welding said bevel portions; and performing a decorative welding wherein the distance between the toe of a 1^{st} weld bead situated at the furthest position from the beveled end on the aforesaid surface side in the aforesaid member having a bevel and the toe of a 2^{nd} weld bead lap-welded on said 1^{st} weld bead is 15 mm or less, up to a distance range of at least 5 mm in the axial direction of the aforesaid member having a bevel from the bevel on the surface side of the aforesaid member having a bevel.

[0017] In addition, the present invention is a method for welding and joining a structural member having a bevel in at least one member, which is characterized by comprising the steps of: performing a decorative buildup welding on the aforesaid member having a bevel wherein the distance from the toe of a 1^{st} weld bead situated at the furthest position from the beveled end on the aforesaid surface side in the aforesaid member having a bevel to the upper end of a 2^{nd} weld bead lap-welded on said 1^{st} weld bead being 15 mm or less, up to a distance range of at least 5 mm in the axial

direction from the beveled end on the surface side; and butting the end portions of the aforesaid decorative buildup-welded member and another member to be welded with one another and welding them to the aforesaid beveled portion and the upper layer of the aforesaid decorative buildup-welded portion.

[0018] Still further, the present invention is a welded joint of a structural member having a bevel in at least one member, which is characterized by having a decorative buildup welded portion which was decoratively welded up to a distance range of at least 5 mm in the axial direction of the aforesaid member having a bevel.

[0019] Moreover, the present invention is a welded joint of a structural member having a bevel in at least one member, which is characterized by having a decorative buildup welded portion wherein the distance from the toe of a 1^{st} weld bead situated at the furthest position from the beveled end on the aforesaid surface side in the aforesaid member having a bevel to the toe of a 2^{nd} weld bead lap-welded on said 1^{st} weld bead being 15 mm or less, up to a distance range of at least 5 mm in the axial direction of the aforesaid member having a bevel from the butt welded portion of said beveled portion and successively the beveled end on the surface side of the aforesaid member having a bevel

[0020] In addition, the present invention is a welded joint of a structural member having a bevel in at least one member, which is characterized by having a decorative buildup weld heat affected

portion nearly parallel to the surface of the aforesaid structural member having a bevel and whose toughness was improved by said decorative buildup welding by performing a decorative buildup welding comprising a plurality of weld beads in the axial direction from the beveled end on the surface side for said member having a bevel.

[0021]

[Embodiments of the Invention] <Embodiment 1>

Figures 1(a) and (b) are cross sections explaining the method for welding a structural member pertaining to Embodiment 1 of the present invention by following steps. (a) shows a state in which butt welding has ended and (b) shows a state in which decorative buildup welding (called “decorative buildup” hereinafter) 31 has ended. In Figure 1(b), a bevel 110 is machined at the end portion of a column 11, and welded to the through-diaphragm 20. The decorative buildup 31 is performed on the column 11 side of the welding metal 30 by butt welding.

[0022] Thus, two types of HAZs are generated on the column 11, i.e., a welding metal heat affected zone (HAZ 1) 40 nearly parallel to the bevel face attributed to the welding metal 30 and a decorative buildup heat welding zone (HAZ 2) 41 substantially parallel (at a low angle) to the surface of the column attributed to the decorative buildup 31. Consequently, when the welded portion is bent, surface cracks are generated in the decorative buildup 31, these surface cracks pass through the decorative buildup 31 and the decorative

buildup heat affected zone (HAZ 2) 41 and are propagated into the column 11 in the direction of the arrow X.

[0023] <Embodiment 2>

Figures 2(a) and (b) are cross sections explaining the method for welding a structural member pertaining to Embodiment 2 of the present invention following steps. (a) shows a state in which the decorative buildup 31 was performed prior to butt welding and (b) shows a state in which butt welding has ended after the decorative buildup 31. The respective reference symbols in Figure 2 are displayed in accordance with the reference symbols in Figure 1.

[0024] In Figure 2, a bevel 110 is machined at the end portion of column 11, and decorative buildup 31 is performed prior to welding by butt welding to the through-diaphragm 20. Butt welding is performed after welding by decorative buildup 31. In this case, the decorative buildup 31 is not affected by the butt welding, so the welding accuracy by decorative buildup 31, and also, the state of the decorative buildup heat affected zone (HAZ 2) 41 can be obtained in the preferred form due to the decorative buildup 31.

[0025] That is, in the case of this Embodiment 2, it is advantageous that accuracy can be obtained in the decorative buildup heat affected zone (HAZ 2) 41 by decorative buildup 31, completely irrespective of the accuracy of the butt welding. According to this method, the length and thickness of the HAZ 2 largely affecting the

advancing direction of the cracks generated in the welded portion can be controlled and the proper length and thickness can be defined.

[0026] By performing the decorative buildup 31 prior to the butt welding, the accuracy of the HAZ 2 can be increased by means of the decorative buildup 31, irrespective of the operating accuracy of the butt welding, and the preferred HAZ 2 state can be obtained.

[0027] Moreover, in order to anticipate strength, a decorative buildup 31 at or greater than a certain thickness is preferable. The welding overlay thickness at the position at the beveled end on the surface side of a member having a bevel is preferably a thickness of at least about 0.1 t (provided t is the plate thickness of the member having the bevel). Moreover, when the overlay thickness at this part is 0.1 t or less, the strength of the welded portion is insufficient, and there is the possibility of cracks being generated from the welding metal portion ahead of the vicinity of the HAZ 2.

[0028] <Embodiment 3>

Figure 3 is a welded joint of the structural member pertaining to another Embodiment 3 of the present invention. In particular, it is a cross-sectional explanatory diagram focusing on the cross-sectional shape of the weld bead. In addition, Figure 4 is a cross-sectional explanatory diagram of a welded joint focusing on the HAZ 2. 311 is a 1st weld bead; 312 is a 2nd weld bead; 313 is a 3rd weld bead; 40 is the welding metal heat affected zone (HAZ 1) produced along a nearly bevel surface; 41 is the decorative buildup heat affected zone

(HAZ 2) produced nearly parallel to the member surface; A is the distance to the toe of the 1st weld bead situated at the furthest position from the beveled end on the surface side of the member having a bevel (called "K" hereinafter) and B denotes the distance from the toe of the aforesaid 1st weld bead to the toe of the 2nd weld bead lap welded on the 1st weld bead. The remaining reference symbols correspond to the reference symbols in Figures 1 and 2.

[0029] In order to confirm the advantages of the present invention, the following tests were performed. Assuming the weld bead toe portion situated at the furthermost position from the beveled end on the surface side is the starting point of a crack in a member having a bevel, a notch (2 mm v-notch, shown by point C in Figure 5) is formed in the surfaces of Charpy impact test pieces collected so that the test piece surfaces are at a position −1 mm from the member surface. Figure 5 shows the state thereof and Figure 6 shows the notch position of the test piece. This notch was provided at positions at distances a of 2, 5, 10 and 15 mm from the bevel end (point K) on the surface side of the member having a bevel. Distance a herein is a distance from the welded joint to the outside in the axial direction of the member having a bevel.

[0030] The Charpy impact test results at 0°C for these test pieces are shown in Figures 7 and 8. In Figure 7, the distance a from point K was plotted on the X axis and the absorbed energy at the fracture transition temperature of each welded portion was plotted on

the Y axis. It was seen from Figure 7 that the toughness increased when the distance a from point K was 5 mm or greater. Moreover, it is favorable that the distance a be set about three times the plate thickness of the member, from the standpoint of welding cost.

[0031] Moreover, in Figure 8, a distance B from the toe of the aforesaid 1st weld bead to the toe of the 2nd weld bead lap-welded on the 1st weld bead was plotted along the X axis, and the percentage (toughness reduction rate) when the maximum value of the absorbed energy at the fracture transition temperature was defined as 1 was plotted along the Y axis. It was evident from Figure 8 that the absorbed energy was confirmed to be 90% or above the maximum value when the distance B from the toe of the 1st weld bead to the toe of the 2nd weld bead was 15 mm or less. Furthermore, when this distance B is 8 mm or less, the advantages thereof are significant.

[0032] More specifically, by the welding of a column and diaphragm for a column-beam joint, the maximum stress point is normally generated at a position slightly farther from the diaphragm (e.g., about 3t; t: plate thickness of the member) due to the overlay height of the weld bead and the restricting effects of the diaphragm. The restricting effects of this diaphragm and also the toughness of the welded portion are improved by the welding method of the present invention, and the safety with respect to the occurrence of cracks behind the vicinity of the bevel face can be further enhanced. The same advantages are also obtained in the welding of a beam flange and

a diaphragm. Furthermore, if the weld bead face is finished smooth, better safety can be obtained.

[0033] Moreover, it is favorable to machine the 2nd weld bead lap welded on the 1st weld bead situated at the furthest position from the beveled end on the surface side for the member having a bevel immediately after welding the 1st weld bead to obtain a reheating effect by welding in the welding heat affected zone. Preferably, welding of the 2nd weld bead is executed prior to the temperature of the 1st weld bead reaching at least 50°C.

[0034] <Embodiment 4>

An actual-size square specimen was manufacture by using a steel pipe as the member having a bevel, and the same test as in Embodiment 3 was performed. As a result, the same results as in the case of Embodiment 3 were confirmed. The same results were also confirmed in a case in which a round steel pipe and a welded and assembled four-sided box were used as the member having a bevel. Moreover, upon manufacturing an actual-size specimen by using a high tensile strength steel for construction as the material of the square steel pipe, and performing the same tests, it was confirmed that high toughness could also be obtained in a welded joint.

[0035]

[Advantages of the Invention] The present invention can obtained the following advantages.

1) Propagation of cracks along the HAZ 1 produced nearly parallel to the bevel face and along the weld line can be avoided.

2) Surface cracks generated in a welded portion can be propagated to within the base material so a reduction in the strength of the welded portion can be kept to a minimum.

3) As a consequence, damage to a welded structural member can be prevented because behavior is based on the mechanical properties of the base material even after cracks are generated.

4) A reduction in the strength of and damage to a joint is prevented more reliably due to a welded joint sufficiently manifesting the performance of a steel plate having higher quality and strength, and a welded structure can be provided with more reliability.

[Brief Explanation of the Drawings]

[Figure 1] In the steps in Embodiment 1 of the present invention, (a) is a cross section showing a state in which butt welding has ended and (b) is a cross section showing a state in which decorative buildup welding has ended.

[Figure 2] In the steps of Embodiment 2 of the present invention, (a) is a cross section showing a state in which decorative buildup welding has ended and (b) is a cross section showing a state in which butt welding has ended.

[Figure 3] A cross-sectional explanatory diagram of the welded joint of a structural member in Embodiment 3 of the present invention.

[Figure 4] A cross-sectional explanatory diagram of the welded joint of a structural member in Embodiment 3 of the present invention.

[Figure 5] A cross-sectional explanatory diagram showing a sampling position of a Charpy impact test piece in Embodiment 3 of the present invention.

[Figure 6] An explanatory diagram showing the notch position of the test piece in Figure 5.

[Figure 7] A chart showing a relationship between the distance a and the absorbed energy in Embodiment 3 of the present invention.

[Figure 8] A chart showing a relationship between the distance B and the toughness reduction rate in Embodiment 3 of the present invention.

[Figure 9] A cross-sectional explanatory diagram of a welded joint in a conventional welding technology.

[Figure 10] A cross-sectional explanatory diagram explaining decorative buildup welding in conventional welding technology.

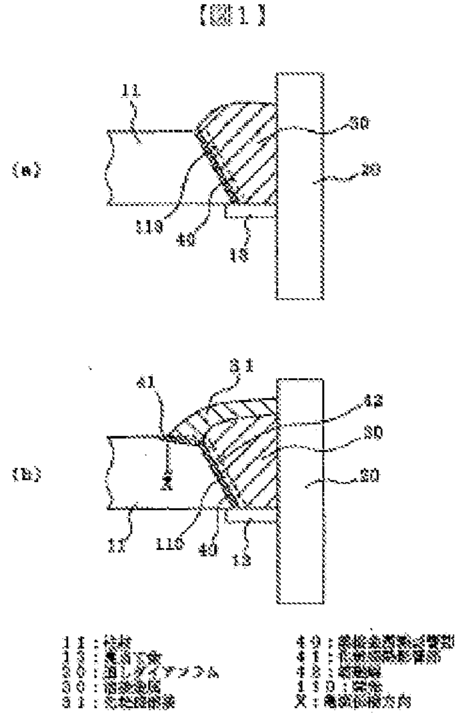
[Figure 11] An explanatory diagram explaining a method for welding a conventional construction structural member.

[Explanation of the Reference Numerals]

11: column; 110: bevel; 13: backing metal; 20: through-diaphragm; 30: welding metal; 31: decorative buildup; 311: 1st weld bead; 312: 2nd weld bead; 313: 3rd weld bead; 40: welding metal heat affected zone (HAZ 1); 41: decorative buildup heat affected zone (HAZ

2); 42: fusion line; 50: Charpy test piece; X: crack propagation direction; K: beveled end on surface side of member having bevel; A: distance from point K to toe of 1st weld bead situated at furthest position from point K; B: distance between toes of 1st weld bead and 2nd weld bead; a: distance from point K to notch position C; C: notch position

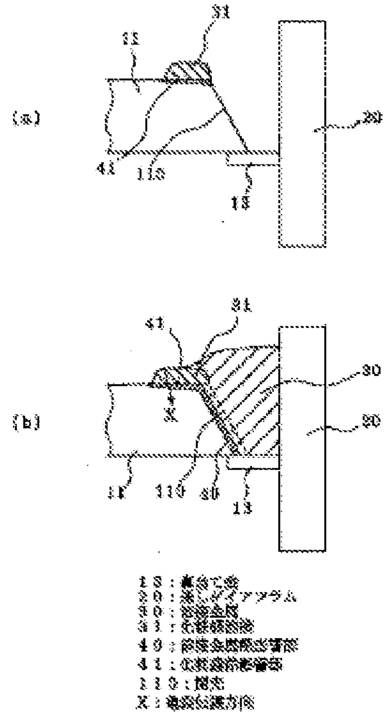
[Figure 1]



Key: 11: column; 13: backing metal; 20: through-diaphragm; 30: welding metal; 31: decorative buildup; 40: welding metal heat affected zone; 41: decorative buildup heat affected zone; 42: fusion line; 110: bevel; X: crack propagation direction

[Figure 2]

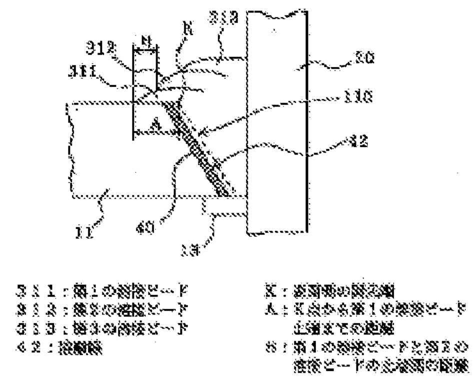
【図2】



Key: 13: backing metal; 20: through-diaphragm; 30: welding metal; 31: decorative buildup; 40: welding metal heat affected zone; 41: decorative buildup heat affected zone; 110: bevel; X: crack propagation direction

[Figure 3]

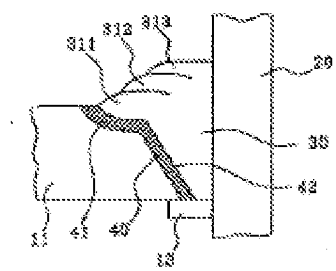
【図3】



Key: 311: 1st weld bead; 312: 2nd weld bead; 313: 3rd weld bead; 42: fusion line; K: beveled end on surface side; A: distance from point K to toe of 1st weld bead; B: distance between toes 1st weld bead and 2nd weld bead

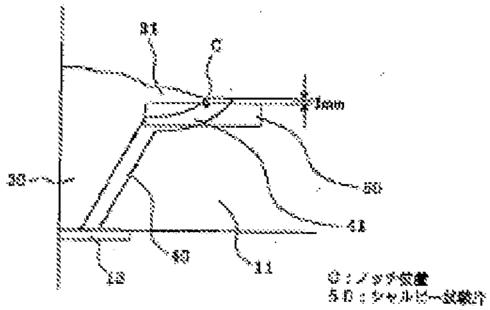
[Figure 4]

【図4】



[Figure 5]

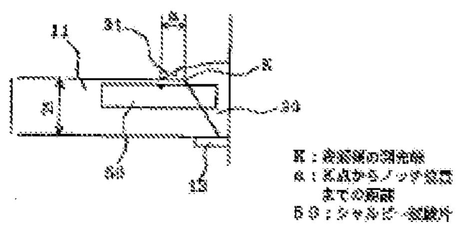
【図5】



C: notch position; 50: Charpy test piece

[Figure 6]

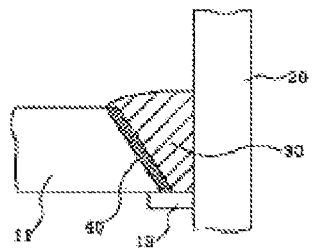
【図6】



K: beveled end on surface side; a: distance from point K to notch position; 50: Charpy test piece

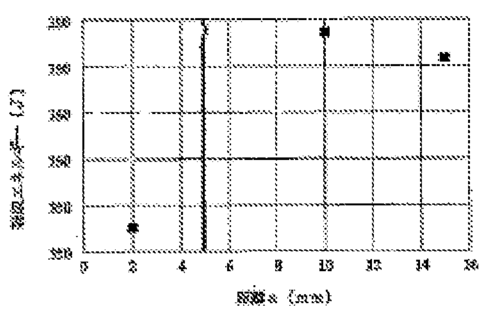
[Figure 9]

【図9】



[Figure 7] /7

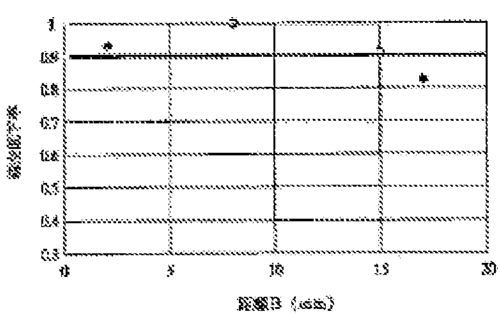
【図7】



Key: (X-axis) Distance a (mm); (Y-axis) Absorbed energy (J)

[Figure 8]

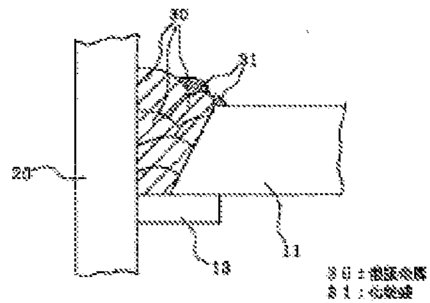
【図8】



Key: (X-axis) Distance B (mm); (Y-axis) Toughness Reduction Rate

[Figure 10]

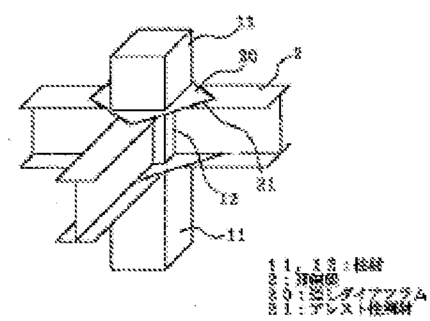
【図10】



30: welding metal; 31: decorative buildup

[Figure 11]

【図11】



11, 12: columns; 2: H-shaped steel; 20: through-diaphragm; 21: steel with arrestability